Missouri
Ground-Water Quality

In Missouri, about 34 percent of the population (fig. 1) obtains water supplies from ground-water sources. Ground water is the source of 74 percent of all rural domestic self-supplied water, 75 percent of all irrigation water, and 39 percent of all industrial self-supplied water, excluding water for thermoelectric power generation (U.S. Geological Survey, 1985). Ground water (fig. 2) generally is suitable for most uses except where it is saline. Median concentrations of dissolved solids, hardness, nitrate, fluoride, and sulfate (fig. 2) are less than the primary and secondary national drinking water regulations established by the U.S. Environmental Protection Agency (1986a,b); however, localized contamination from manufactured organic compounds (fig. 3) has been recognized in four principal aquifers in Missouri, including both shallow and deep aquifers.

WATER QUALITY IN PRINCIPAL AQUIFERS

The six principal aquifers in Missouri are: (1) Major river valleys, (2) alluvial (in southeastern Missouri), (3) Wilcox and Claiborne, (4) McNairy, (5) Ozark and (6) Kimmswick-Potosi (fig. 2). These aquifers, which underlie about 60 percent of the State, have differing water quality.

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality constituents compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) is presented in figure 2C. The summary is based on dissolved-solids, hardness, nitrate, fluoride, and sulfate analyses of water samples collected from 1930 to 1986 from principal aquifers in Missouri. Percentiles of these constituents are compared to national standards that specify the maximum concentration or level of a contaminant in a drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include maximum concentrations of 10 mg/L (milligrams per liter) nitrate (as nitrogen) and 4.0 mg/L fluoride, and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids, 250 mg/L sulfate and 2.0 mg/L fluoride. The summary (fig. 2C) indicates that median dissolved-solids concentrations in ground water from all six principal aquifers are less than 500 mg/L; median hardness concentrations are less than 400 mg/L as calcium carbonate; median concentrations of nitrate are less than 0.10 mg/L as nitrogen; median concentrations of fluoride are 0.30 mg/L or less (except the Kimmswick-Potosi aquifer which is 1.0 mg/L); and median concentrations of sulfate are less than 60 mg/L.

About 40 percent of the aquifer systems in the State contain saline water, that is unusable for most purposes. Concentrations of dissolved-solids, chloride, sulfate, and other constituents in this saline water greatly exceed the national drinking water standards. Generally, saline water is located in northern, western, and southeastern Missouri (fig. 3B). The saline water-freshwater transition zone, defined as the zone where dissolved-solids concentration is larger than 1,000 mg/L, is located at the northwestern and southwestern margins of the Ozark and Kimmswick-Potosi aquifers (fig. 3B).

Along the transition zone, use of ground water for irrigation has increased rapidly during the past 20 years, causing water levels to decline about 100 feet in the Ozark aquifer in western

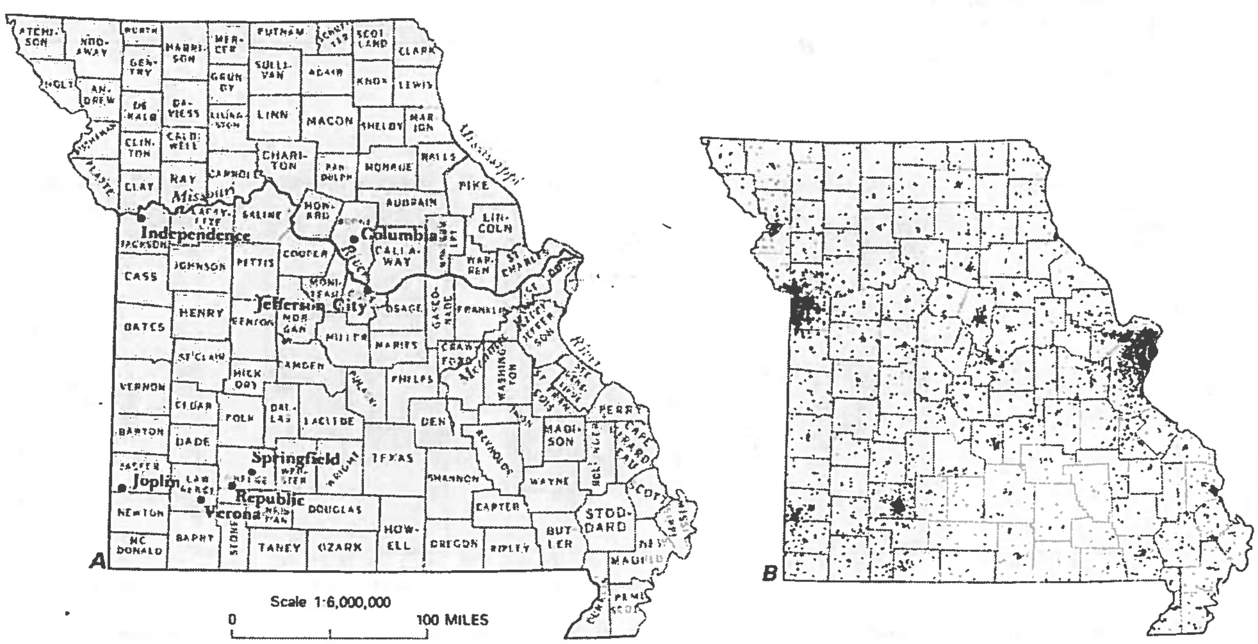


Figure 1. Selected geographic features and 1985 population distribution in Missouri. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

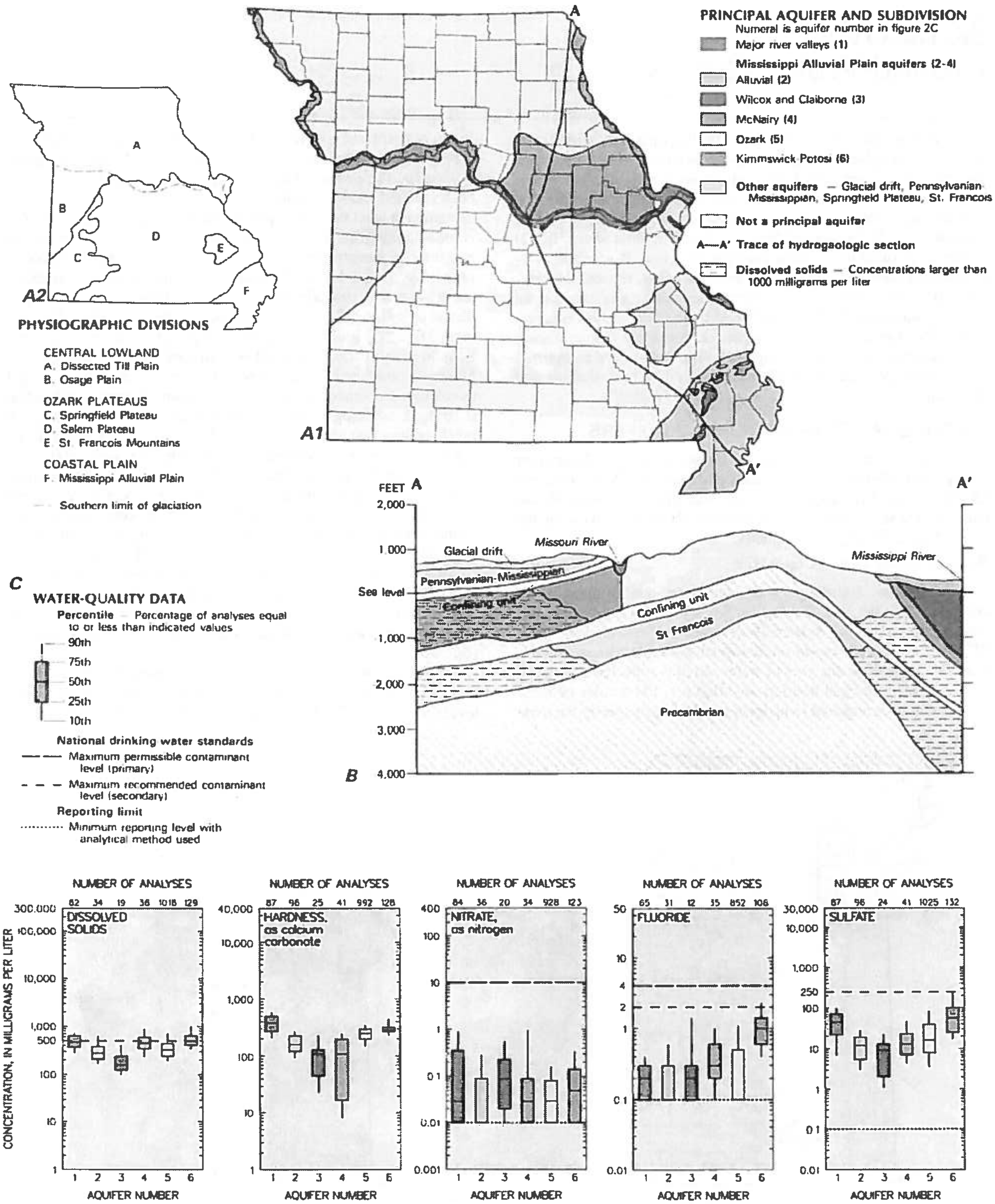


Figure 2. Principal aquifers and related water-quality data in Missouri; *A1*, Principal aquifers; *A2*, Physiographic provinces. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1930-86. (Sources: *A1*, U.S. Geological Survey, 1985. *A2*, Fenneman, 1938; Raisz, 1954. *B*, U.S. Geological Survey, 1985. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986 a, b.)

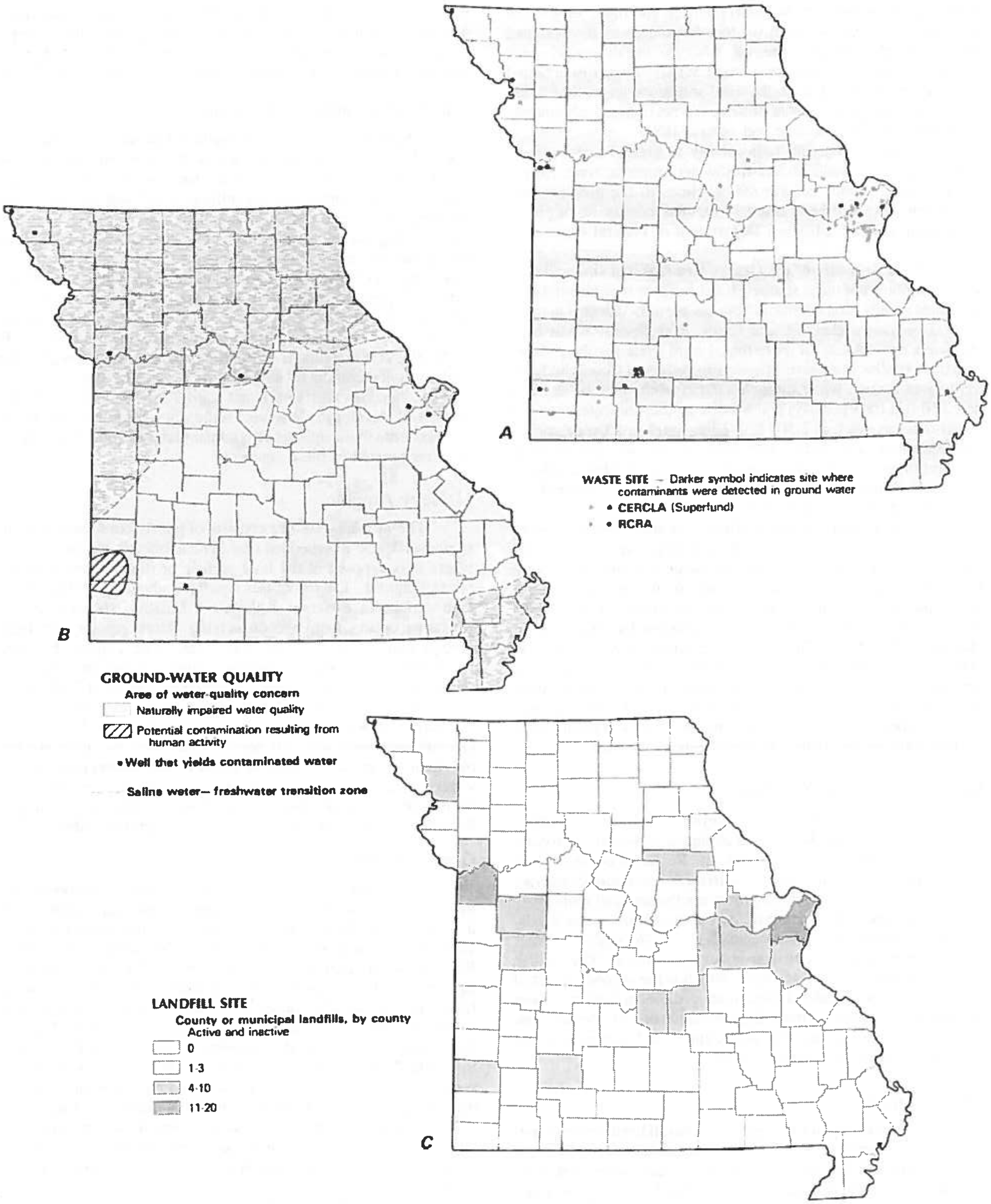


Figure 3. Selected waste sites and ground-water-quality information in Missouri. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; and Resource Conservation and Recovery Act (RCRA) sites, as of 1986. *B*, Areas of naturally impaired water quality, area of potential contamination, and distribution of wells that yield contaminated water, as of 1986. *C*, County and municipal landfills, as of 1986. (Sources: *A*, U.S. Environmental Protection Agency, 1986c; Missouri Department of Natural Resources, 1986d. *B*, Missouri Department of Natural Resources, 1986b. *C*, Missouri Department of Natural Resources, 1986c.)

Missouri (Kleeschulte and others, 1985), and in the Kimmswick-Potosi aquifer in northern Missouri (Emmett and Imes, 1984). Use of several irrigation wells in western Missouri was discontinued because of salt build-up in the soil. Also, the use of ground water for several public supplies in western Missouri was discontinued because the concentration of dissolved-solids was larger than 2,000 mg/L, even though the quality of water has not changed substantially in recent years (Kleeschulte and others, 1985).

Naturally occurring radioactivity in ground water also is associated with the saline water-freshwater transition zone. Deeply buried geologic units release radionuclides to the groundwater. These releases have been noted in regular monitoring of public water-supply wells (Missouri Department of Natural Resources, 1986b).

The karst nature of the Ozarks area makes it susceptible to contamination from many sources. Karst conduits may transmit contaminants rapidly, and interbasin flow has been documented in many areas. Dye-trace studies at Logan Creek, in south-central Missouri, indicate a dye velocity of more than 1 mi/d (mile per day). Other dye-trace studies in eastern Missouri in Jefferson County indicate velocity of ground water through karst conduits may be as much as 1,860 ft/d (feet per day) and historic studies indicate some dye travel-times as much as 2,500 ft/d (Kleeschulte and Duley, 1985). Dye-trace studies in southwestern Missouri indicate a greater range of travel times. Dye moving through a karst conduit had a velocity of about 1.3 mi/d, but dye moving through alluvial material had a velocity of about 54 ft/d (Barks and others, 1983).

Stream-aquifer interaction affects almost all stream channels. This interaction can vary seasonally and from site to site along a single stream. Ground water may discharge to a stream, or if the stream-bed elevation is sufficiently high or the geology permits, water may be lost from the stream into the ground-water system. A prominent example of flow loss to the subsurface was cited by Harvey (1980). Logan Creek was determined to have lost about 200 cubic feet per second of water between its upstream and downstream reaches. Kleeschulte and Duley (1985) reported streams in Jefferson County may lose or gain water from the ground-water system. Other examples of losing streams have been documented by Barks and others (1983) in southwestern Missouri.

Major River Valleys Aquifers

Aquifers of the major river valleys consist of unconsolidated gravel, sand, silt, and clay located along the Missouri, Mississippi, and lower Meramec Rivers (fig. 2). Recharge occurs by upward movement from underlying bedrock, stream-aquifer interaction, and precipitation. These aquifers are the surficial units along these rivers, are very permeable, and have shallow water levels. The median dissolved-solids concentration was 467 mg/L (fig. 2*C*); the maximum concentration was about 2,100 mg/L. The median sulfate concentration was 45 mg/L, which is the second largest of principal aquifers. Localized human-induced contamination of these aquifers has occurred at more than 30 sites (fig. 3). Primary use of water from this aquifer is for public supply at Independence and Columbia, and in St. Charles County.

Alluvial Aquifer

The alluvial aquifer consists of unconsolidated gravel, sand, silt, and clay located in the Mississippi Alluvial Plain of southeastern Missouri (fig. 2). Recharge occurs by upward movement from underlying bedrock near the margin of the Mississippi Alluvial Plain, stream-aquifer interaction, and precipitation. This aquifer is a surficial unit that is very permeable and has shallow water levels that range from 5 to 10 feet below land surface (Luckey, 1985). The median dissolved-solids concentration was 275 mg/L (fig. 2*C*); maximum concentration was about 1,100 mg/L. The median concentration of nitrate (as nitrogen) was less than 0.01 mg/L, which is the minimum detection limit. The area has been intensively developed for agricultural purposes and the aquifer is the principal source of water for irrigation. Localized human-induced contamination has occurred at two sites in southeastern Missouri (fig. 3).

Wilcox and Claiborne Aquifers

The Wilcox and Claiborne aquifers function as a multiaquifer unit and consist of interbedded layers of unconsolidated sand and clay located beneath the alluvial aquifer in southeastern Missouri (fig. 2). These aquifers are unconfined in and near outcrop areas, but are confined near the Mississippi River. Recharge occurs from the overlying alluvial aquifer, from precipitation, and possibly from the upward movement of water from the underlying McNairy and Ozark aquifers through localized fracture zones. These aquifers are exposed in parts of southeastern Missouri, but generally are covered by several hundred feet of alluvium. These aquifers have moderate permeability. The median dissolved-solids concentration was 159 mg/L (fig. 2*C*); maximum concentration was about 660 mg/L. The median concentration of sulfate was 9.2 mg/L, which was the smallest value for all six principal aquifers. This unit has not been intensively developed; however, some water for public supplies is pumped from these aquifers. No human-induced contamination has been recognized in these aquifers.

McNairy Aquifer

The McNairy aquifer consists of poorly consolidated sandstone, sand, and interbedded clay. The aquifer is confined except where it is exposed at the land surface or directly underlies the alluvial aquifer. The top of this aquifer is about 2,100 feet below land surface in extreme southeastern Missouri (Mesko, 1987). Recharge occurs from the underlying Ozark aquifer and from precipitation falling on outcrop areas. The aquifer has low permeability. The median dissolved-solids concentration was 448 mg/L (fig. 2*C*); the maximum concentration was about 2,200 mg/L in areas where saline water from the Ozark aquifer (fig. 2*B*) discharges upward. The median concentration of hardness as calcium carbonate was 110 mg/L, which was the same for the overlying Wilcox and Claiborne aquifers. Substantial quantities of water for public supplies are pumped from this aquifer. Only rare occurrences of human-induced contamination caused by coliform bacteria in public-supply wells have been recognized in this aquifer.

Ozark Aquifer

The Ozark aquifer consists of consolidated dolomite and minor layers of sandstone. This aquifer is confined except where it is exposed at the land surface. The top of this aquifer is about 1,000 feet below land surface in western Missouri (Imes, 1987). Recharge occurs from precipitation, from overlying and underlying aquifers, and from stream-aquifer interaction south of the Missouri River. The permeability varies considerably where solution activity has created karst conditions that allow rapid movement of water. The median dissolved-solids concentration was 322 mg/L (fig. 2*C*). In southeastern, western, and northern Missouri, water in this aquifer becomes saline, with a maximum dissolved-solids concentration larger than 5,000 mg/L. Substantial quantities of water for public, irrigation, industrial, and domestic supplies are pumped from this aquifer. Localized human-induced contamination occurs in this aquifer (fig. 3) from hazardous waste, landfills, and other sources.

Kimmswick-Potosi Aquifer

The Kimmswick-Potosi aquifer consists of consolidated dolomite and some sandstone that are generally confined. The top of this aquifer is about 1,800 feet below land surface (U.S. Geological Survey, 1985). This aquifer is a primary source of water in a seven-county area north of the Missouri River. Recharge occurs primarily from precipitation infiltrating overlying aquifers. The aquifer has low permeability. The median dissolved-solids concentration was 489 mg/L (fig. 2*C*). The maximum dissolved-solids concentration was about 4,700 mg/L to the north where water becomes saline. The median concentration of fluoride was 1.0 mg/L and sulfate was 56.0 mg/L, which were the largest median values of all six principal aquifers. No human-induced contamination has been recognized in this aquifer.

EFFECTS OF LAND USE ON WATER QUALITY

Ground-water concerns in Missouri have been identified by the Missouri Department of Natural Resources (MDNR) (1986a,b). MDNR (1986b) ranked the most important sources of ground-water contamination in the State, in order of decreasing importance as follows: abandoned hazardous waste sites (including radioactive waste sites), surface impoundments, underground storage tanks, and septic systems. Other major sources that have the potential to contaminate ground water are: solid-waste landfills, surface and underground mining, wells, transport, and agriculture. Human-related activities appear to be the most significant source of current (1986) and potential changes to ground-water quality.

Hazardous-Waste Sites

Twelve sites in Missouri (fig. 3*A*) have been evaluated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and have been included in the National Priorities List (NPL) (U.S. Environmental Protection Agency, 1986c). Ground water is contaminated at seven of these sites. Also, 44 sites have been evaluated under the Resource Conservation and Recovery Act (RCRA) of 1982 (fig. 3*A*). Ground water has been contaminated at nine of these sites. The MDNR annually compiles a registry of confirmed, abandoned, or uncontrolled hazardous-waste sites in the State which include some, but not necessarily all, CERCLA and RCRA sites. A total of 81 sites has been proposed for the State registry, and currently (1986) 50 sites are listed in this registry (Missouri Department of Natural Resources, 1986d). Of these 50 sites, 23 are contaminated with dioxin (2, 3, 7, 8-tetrachlorodibenzo-p-dioxin).

Dioxin was formed as a byproduct in the manufacture of the herbicide Agent Orange, and the antiseptic hexachlorophene. Dioxin-contaminated waste oil was spread on roads and in horse stables for dust control at 45 sites in the state (Catherine Barrett, U.S. Environmental Protection Agency, oral commun., 1986).

During 1973, roads in the city of Times Beach (St. Louis County) were contaminated with dioxin. Subsequently, starting in 1983, the U.S. Environmental Protection Agency (EPA) relocated residents and purchased property in the affected areas (Catherine Barrett, U.S. Environmental Protection Agency, oral commun., 1986). Other major areas in Missouri affected by dioxin include facilities at Verona and Springfield where the byproduct was manufactured or stored, and areas in and near St. Louis County. Excavated material contaminated with dioxin was used as fill-dirt in some residential areas.

The city of Republic's well 1 was removed from service after being contaminated with trichloroethylene (TCE). Concentrations of this chemical were as much as 140 μg/L (Missouri Department of Natural Resources, 1986d), exceeding the national drinking-water standard of 27 μg/L.

Ground water at two sites in Missouri has been contaminated with low-level radioactive waste. Four pits and a quarry located at Weldon Spring (St. Charles County) were used to dispose waste generated by a uranium processing plant (Kleeschulte and Emmett, 1986). Locally, the bedrock aquifer (fig. 3) and Burgermeister Spring (St. Charles County) have been found to be contaminated with nitrates, lithium, and uranium (Kleeschulte and others, 1986).

Surface Impoundments

Storage and treatment lagoons are used to contain chemical byproducts and residues, and allow natural biodegradation of sanitation waste. Privately owned lagoons are not required to be licensed or inspected; therefore, no estimates are available on the total number of privately owned lagoons in the State. Operators of lagoons that discharge treated animal or human waste into streams must obtain a permit under the National Pollutant Discharge Elimination System (NPDES). About 1,200 lagoons have been permitted by the MDNR under NPDES. In addition, the Department estimates that 1,300 lagoons are used as nondischarging storage facilities for wastes. The Department estimates that another 1,300 lagoons are operated for purposes that do not require permits. About 30 surface impoundments are used to store liquid chemical waste (John Ford, Missouri Department of Natural Resources, Division of Environmental Quality, oral commun., 1986).

Sudden formation of sinkholes may cause surface-impoundment failures. During 1966, a major lagoon operated by the city of West Plains (Howell County) collapsed and leaked about 136 acre-feet of effluent in 52 hours, or an average rate of about 30 cubic feet per second (Aley and others, 1972). Later data indicated that the effluent was traced to Mammoth Spring, Arkansas, about 25 miles distant (James E. Vandike, Missouri Department of Natural Resources, oral commun., 1986).

A sewage lagoon operated by the city of Republic suddenly collapsed in 1968. An estimated 4 million gallons of sewage entered the ground-water system. Dye and effluent were traced 1 to 1.5 miles from the lagoon, reappearing in two domestic wells (Aley and others, 1972).

Underground Storage Tanks

Leakage from underground storage tanks is a relatively new and potentially widespread problem. Estimates indicate that as many as 25 percent of underground storage tanks may leak (Missouri Department of Natural Resources, 1986a). The Department currently (1986) is compiling an inventory of all underground storage tanks in Missouri, excluding those used for private-home heating oil. A total of 23,000 tanks have been inventoried, about one-half of the estimated total based on studies in other parts of the country (Gordon Ackley, Missouri Department of Natural Resources, written commun., 1986). About 90 percent of these tanks contain petroleum-related products and the remainder contain chemicals. The Department's Emergency Response Team has investigated about 135 reports of leaking underground storage tanks from 1980 to 1986.

Septic Tanks

Waste from septic-tank leach fields can contaminate ground-water systems with untreated sewage. In urban areas, this problem is compounded by closely spaced homes, each utilizing private septic systems. Wells withdrawing water may induce a more rapid downward infiltration of leachate from overlying surficial material. Where water levels are shallow, as in alluvial aquifers, leachate may have to travel only 5 to 10 feet downward before reaching ground water. Shallow wells, used as drinking-water supplies, may be affected by this relatively unfiltered leachate.

Solid-Waste Landfills

Missouri's Solid Waste Management Law (1972) requires that all solid-waste landfills operated since 1972 must be operated under a permit and inspected periodically. No information is available to determine the location of landfills operated before 1972 or the type of waste that landfills have received. Currently (1986), 220 permitted solid-waste landfills (fig. 3*C*) are in the State, of which 128 are active and 92 are inactive. The MDNR classifies landfills according to the type of facility and waste received. The largest category is sanitary landfills, of which there are 101 active and 65 inactive sites (Miles Stotts, Missouri Department of Natural Resources, written commun., 1986).

No estimates are available on the total number of private or non-permitted landfills; however, the MDNR currently is compiling an inventory of these types of landfills. Landfills that are not operated under permits represent a potential source of contamination to ground-water systems. Several examples of non-permitted landfills containing toxic materials have been documented (Missouri Department of Natural Resources, 1986d).

Fullbright landfill, located near Springfield, has been placed on the National Priorities List of CERCLA sites. This non-permitted site contains cyanide, acid, plating residues, trichloroethylene (TCE), paint, waste oil, and pesticide residue (Missouri Department of Natural Resources, 1986d). In 1967, one person died from cyanide poisoning and another person was overcome by fumes at the site (Missouri Department of Natural Resources, 1986d).

Westlake landfill, located in St. Louis County, accepted solvents, pesticides, acids, and material containing radionuclides. The site has been contaminated with 4,000 tons of chlordane, trichloroethylene, and toluene, as well as 7,000 tons of low-level uranium-ore waste. The shallow water surface in the alluvium along the Missouri River may provide an easy path for these contaminants to enter the river (Missouri Department of Natural Resources, 1986d).

Surface and Underground Mining

Surface mining of coal and mineral resources occurs in northern, western, and southeastern Missouri. Underground mining of lead and zinc occurs in southcentral Missouri and has been discontinued in southwestern Missouri.

Ground water at coal strip mines, located in western and northern Missouri, is acidic and generally contains large concentrations of dissolved metals. Acid drainage from these mines may contaminate surface- and ground-water supplies. The MDNR Land Reclamation Program has undertaken reclamation projects at several abandoned sites in the State. At an abandoned coal strip mine and processing plant in western Missouri, before reclamation, ground water had a dissolved-solids concentration of 10,000 mg/L and pH values as small as 2.3. The concentration of total iron was 1,800,000 μg/L (micrograms per liter) and sulfate was 6,300 mg/L (data from U.S. Geological Survey files). A spring discharging from the mine site had a dissolved-solids concentration of about 8,500 mg/L. After reclamation, dissolved-solids concentration in the spring discharge decreased to about 3,800 mg/L. Ground water in the Macon County area of northern Missouri has been locally affected by coal strip mining. In this area, the reported concentrations of selected constituents were: dissolved-solids, 18,000 mg/L; iron, 29,000 μg/L; and sulfate, 400 mg/L. The pH values were as small as 4.2 (Hall and Davis, 1986). Ground water in this area generally is not used; however, water from springs and seeps at these sites can flow into streams that are used as public supplies.

Missouri has been a leading producer of lead and zinc ore since the 1800's. Numerous abandoned lead and zinc mines that are now flooded are located in southwestern Missouri near the Joplin and Webb City (Jasper County) areas. Water in these mines typically contains larger than normal concentrations of dissolved solids and metals. The average dissolved-solids concentration was reported to be more than 1,000 mg/L, dissolved lead was reported to be 10 μg/L, and zinc was reported to be about 9,400 μg/L (Barks, 1977). Webb City, which obtains water from the Ozark aquifer underlying the abandoned mine area, removed a well from service because the water contained excessive dissolved solids. Lead and zinc ore also is produced in southeastern Missouri. Two ground-water samples collected from the Ozark aquifer in this area had lead concentrations of 59 and 106 μg/L, which exceed national drinking-water standards of 50 μg/L.

Wells

Water wells and test wells that have been abandoned or were improperly constructed may allow contamination of potable water supplies. Water-well drillers must now be licensed in the State, which will decrease the occurrence of well-casing failure because of improper construction. Public-supply wells and exploratory holes for oil, gas, and minerals must be plugged if abandoned; however, numerous abandoned private wells and old exploration holes that were not plugged have been documented (Missouri Department of Natural Resources, 1986b). Surface contamination may enter the ground-water system through these wells and open holes. Also, these wells and open holes may provide an interaquifer path for contaminated water to enter adjacent freshwater aquifers. Injection wells regulated under the Underground Injection Control Program (U.S. Environmental Protection Agency, 1984) may allow contamination of water supplies. In the State, no wells are used to inject hazardous, industrial, or municipal wastes underground that have been categorized by the EPA (1984) as Class I wells. Currently (1986), there are a total of 542 Class II wells used for recovery of oil and gas, 447 Class V wells used for ground-water heat pumps, 250 Class V storm drainage wells which use sinkholes to accept storm runoff, and 4,326 Class V wells and shafts associated with mine back fill (K.L. Deason, Missouri Department of Natural Resources, written commun., 1986).

Transport

Crude oil, refined petroleum products, liquified propane gas, and bulk fertilizers are transported through Missouri by a network of pipelines. Numerous other materials are transported by railroad and highway. Pipeline breaks, train derailments, and trucking mishaps can cause contaminants to "locally" enter ground-water systems. In Missouri, about 2,000 miles of pipeline transport crude oil and about 2,600 miles of pipeline transport refined petroleum products, liquified propane gas, and bulk fertilizers (Missouri Department of Natural Resources, 1982). Contamination of ground water by pipeline leaks has occurred in Missouri. One such leak occurred in central Missouri during 1981, when fertilizer leaked from a pipeline, traveled down a stream, and entered the ground-water system through a losing section of stream. About 8 days later, fertilizer appeared in a major spring about 13 miles from the original spill, damaging aquatic life. A dye-trace study after the spill indicated a flow velocity of about 1.1 mi/d (J.E. Vandike, Missouri Department of Natural Resources, written commun., 1986). Also, spills during railroad and highway transport can cause ground-water contamination in Missouri.

Agriculture

Use of insecticides, herbicides, and fungicides has increased throughout the State for both regulated and non-restricted categories of pesticides. Based on 1984 crop-acreage data (Tauchen, 1985) and an average rate of application for the most commonly used pesticides, an estimated 500,000 pounds of dry and 1 million gallons of liquid pesticides were applied to crops grown in southeastern Missouri. Few data currently (1986) are available on the regional occurrence of pesticides in ground water, and water from only a few test wells in southeastern Missouri has been documented as being contaminated with pesticides (James Burris, Missouri Department of Natural Resources, written commun., 1986). Currently (1986), no agency or program in the State monitors the sale or use of non-restricted pesticides.

A system of drainage ditches was constructed during the early 1900's in southeastern Missouri to drain swamp lands for agricultural use. Water from the shallow alluvial aquifer discharges into

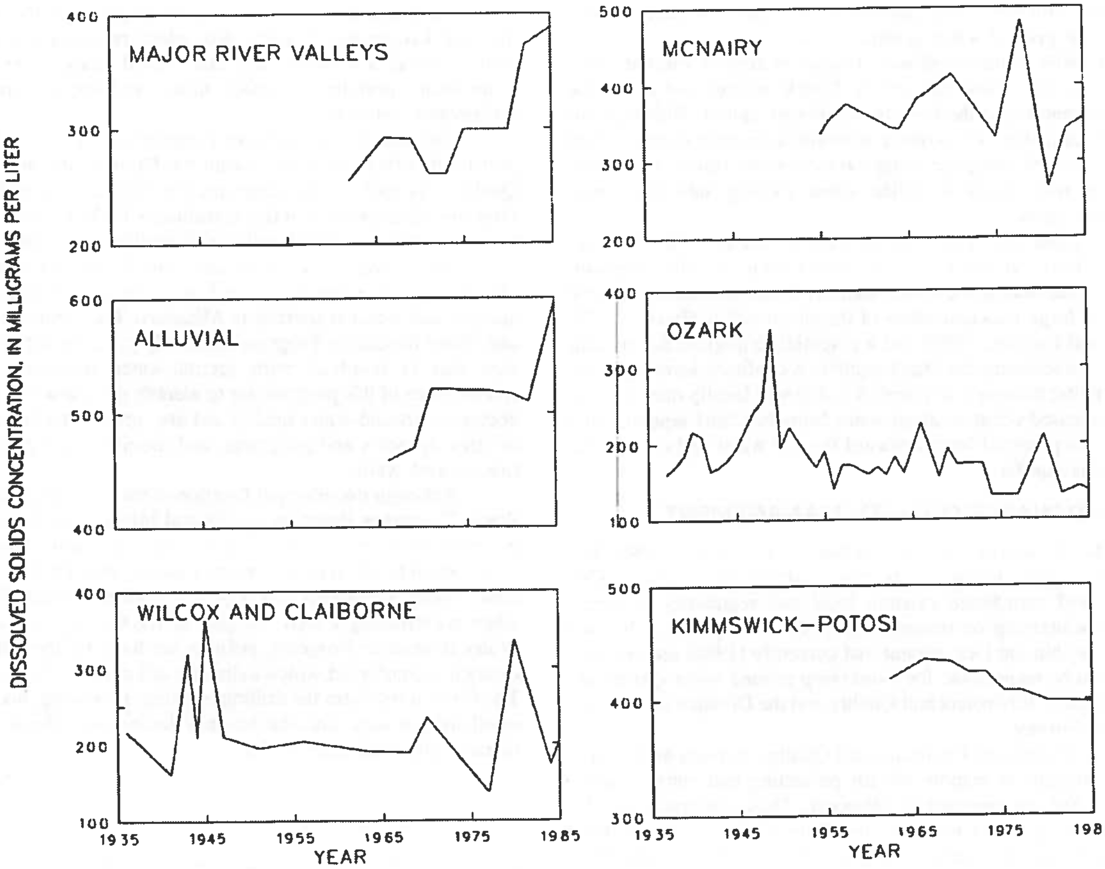


Figure 4. Long-term fluctuations of dissolved-solids concentration in selected wells in the principal aquifers of Missouri, 1936-85. (Source: Missouri Department of Natural Resources, Census of Missouri Public Water Supplies.)

the ditches, and sediment eroded from the surficial material is transported in these ditches. Water, bottom-sediment, and fish-tissue samples collected by the U.S. Army Corps of Engineers (1980) from ditches in Mississippi County indicate "...pesticides dieldrin, diazinon, DDT, benzene hexachloride (BHC), heptachlor, aldrin, DDD, and Lindane were all detected in water at concentrations above the maximum levels for protection of aquatic life. Toxaphene was detected at levels up to 3 μg/L, far above the maximum acceptable level defined by EPA for fish and wildlife."

Luckey (1985) detected aldrin, chlordane, DDD, and DDE in bottom sediments from major rivers and ditches draining southeastern Missouri. The EPA sampled major drainage ditches in southeastern Missouri during 1986 and detected concentrations of atrazine, alachlor, metoalachlor, and parathion in water samples (Norm Crisp, U.S. Environmental Protection Agency, written commun., 1986).

Water-Quality Trends

Water quality in the six principal aquifers fluctuates (fig. 4); however, no long-term degradation has been noted. Dissolved-solids concentrations in water from the alluvial aquifers (major river valleys and southeastern Missouri) have increased slightly since the 1960's, but the duration of data is not sufficient to prove degradation is occurring. Water from the Wilcox, Claiborne, and McNairy aquifers is used primarily for public supplies. Dissolved-solids concentrations have varied about 200 mg/L, but data are insufficient to indicate that water quality is being degraded in these aquifers. Data shown for the Ozark aquifer were compiled for a public water supply in western Missouri located near the saline water-freshwater transition zone. Almost 50 years of data indicate that the water quality has remained relatively constant. Data for other sites near the transition zone (Kleeschulte and others, 1985) indicate that the water quality has not changed since the late 1800's, even though the Ozark aquifer is intensively pumped for public and irrigation water supplies. The Kimmswick-Potosi aquifer is intensively used for public and irrigation supply; however, since the early 1900's water quality in this aquifer has not changed appreciably (Emmett and Imes, 1984).

Potential for Water-Quality Changes

Densely populated areas of Missouri are located adjacent to the Missouri and Mississippi Rivers (fig. 1). The shallow water levels, characteristic of the major river valley aquifers, make these aquifers susceptible to contamination from landfills and accidental industrial spills. Although modern methods of waste disposal are improving, the large quantities of waste from metropolitan areas increase the potential for ground-water contamination.

The shallow water levels in the alluvial aquifer in southeastern Missouri make it susceptible to contamination. This aquifer is used for public, domestic, and irrigation supplies. Contamination can occur because of the large volumes of pesticides used annually on land in the region.

The karst nature of the Ozark aquifer makes it susceptible to contamination from many sources. Once in the ground-water system, rapid flow through the karst conduits provides little filtering of water. Surficial soils and residuum provide some filtering of water; however, in many places these materials may be thin or absent. Also, sinkholes may provide a direct path for contaminants to enter the ground-water system.

A saline water-freshwater transition zone is located along the northwestern boundary of the Ozark aquifer and along the northern boundary of the Kimmswick-Potosi aquifer. Although this transition zone has not moved a substantial distance during recent years, increased pumpage along the freshwater side of the transition zone may result in saline water moving into previously freshwater areas.

In Jasper and Newton counties in southwestern Missouri (fig. 3*B*), past lead and zinc mining has occurred in the Mississippian-age rocks that overlie the Ozark aquifer. Water in these abandoned mines has large concentrations of dissolved solids (Barks, 1977; Harvey and Emmett, 1980) and a potential to migrate downward, thereby contaminating the Ozark aquifer. A confining layer separates the two units; however, in places it is thin and locally may be fractured. Increased withdrawals of water from the Ozark aquifer could increase the potential for downward flow of water and contamination of this aquifer.

GROUND-WATER-QUALITY MANAGEMENT

The Missouri Department of Natural Resources (1986a) has proposed a ground-water protection strategy for the State. This strategy will coordinate existing legal and regulatory authority toward maintaining or restoring ground-water quality. The two agencies within the Department that currently (1986) are and will continue to be responsible for monitoring ground-water quality are the Division of Environmental Quality and the Division of Geology and Land Survey.

The Division of Environmental Quality, through its five programs, currently is responsible for protecting and enhancing the quality of the environment in Missouri. These programs are the Public Drinking Water Program, the Water Pollution Control Program, the Waste Management Program, the Land Reclamation Program, and the Laboratory Services Program.

Under the Public Drinking Water Program, about 985 public water supplies are monitored for bacteriological, chemical, and radiological constituents and properties. Monitoring of public water supplies began in 1919 under the direction of the Missouri Board of Health. Currently (1986) this program enforces the Missouri Safe Drinking Water Standard in accordance with the Federal Safe Drinking Water Act. This standard sets the acceptable levels of various constituents in raw surface and ground water that is used for public water supplies.

Under the Water Pollution Control Program, the policies of the Clean Water Commission and State and Federal clean water laws are implemented. Also, the quality of surface and ground water entering the State is monitored. This program enforces the Missouri Water-Quality Standard, which sets the maximum allowable concentrations of contaminants with respect to the intended use of the water. For example, if a leachate from a coal-spoil pile degrades the quality of nearby ground water that is used for public or domestic drinking supplies, the owners of the spoil pile must improve the ground-water quality so that it meets the Missouri Water-Quality Standard.

Under the Waste Management Program, solid and hazardous waste is regulated to ensure that storage or disposal does not adversely affect ground-water quality. As part of this program, permits are issued to transporters of hazardous waste and to operators of hazardous- and solid-waste disposal facilities. The program inspects these facilities to insure they are properly operated. Under this program, the Division also implements the policies of the Missouri Waste Management Commission, which sets regulations for the transportation, treatment, storage, and disposal of hazardous and non-hazardous wastes.

The Land Reclamation Program implements the policies of the Land Reclamation Commission, which regulates surface mining and reclamation of abandoned coal mined lands. Also, this program issues permits to surface mines and inspects mining and reclamation projects.

The Laboratory Services Program provides technical support to the other programs within the Division of Environmental Quality. As part of this program, the Division maintains an environmental response unit that coordinates Federal, State, and local agencies after accidental spills of hazardous material.

The Division of Geology and Land Survey is responsible for identifying the potential use and development of mineral, land, energy, and water resources in Missouri. The Geological Survey and Water Resources Program is the only program within the Division that is involved with ground-water resources. The responsibilities of this program are to identify ground-water resources, document ground-water quality and use, provide technical support to other agencies and programs, and monitor underground injection control wells.

Although the principal function of the Geological Survey and Water Resources Program is data and information gathering, the program also currently (1986) is writing regulations on water-well construction to accompany a recently passed Well Drillers Licensing Law. These regulations will require that certain standards be used when constructing a well. As part of the Geological Survey and Water Resources Program, policies set forth by the Oil and Gas Council are enforced which indirectly affect ground-water quality. The Council regulates the drilling, spacing, producing, and plugging of oil and gas wells and also has jurisdiction over illegal, malfunctioning, and unplugged wells.

SELECTED REFERENCES

Aley, T.J., Williams, J.H., and Massello, J.W., 1972, Ground water contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain: Rolla, Missouri Division of Geology and Land Survey Engineering Geology Series No. 5, 32 p.

Barks, J.H., 1977, Effects of abandoned lead and zinc mines and tailings piles on water quality in the Joplin area, Missouri: U.S. Geological Survey Water-Resources Investigations 77–75, 49 p.

Barks, J.H., Mesko, T.O., Bohm, R.A., Meier, D.H., and Williams, J.H., 1983, Geology, water movement, and sediment characteristics of the Spring River upstream from La Russell, southwestern Missouri: Rolla, Missouri Division of Geology and Land Survey Open-File Report 83-31-WR, 33 p.

Emmett, L.F., and Imes, J.L., 1984, Ground-water resources of Audrain County, Missouri: U.S. Geological Survey Open-File Report 84–245, 55 p.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

Hall, D.C., and Davis, R.E., 1986, Ground-water movement and effects of coal strip mining on water quality of high-wall lakes and aquifers in the Macon-Huntsville area, north-central Missouri: U.S. Geological Survey Water-Resources Investigations Report 85–4102, 102 p.

Harvey, E.J., 1980, Ground water in the Springfield-Salem plateaus of southern Missouri and northern Arkansas: U.S. Geological Survey Water-Resources Investigations Report 80–101, 66 p.

Harvey, E.J., and Emmett, L.F., 1980, Hydrology and model study of the proposed Prosperity Reservoir, Center Creek basin, southwestern Missouri: U.S. Geological Survey Water-Resources Investigations 80–7, 50 p.

Imes, J.L., 1987, Major geohydrologic units in and adjacent to the Ozarks Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma—Ozark aquifer: U.S. Geological Survey Hydrologic Investigation Atlas HA–711-E, 3 maps. [in press]

Kleeschulte, M.J., and Duley, J.W., 1985, Geology, water movement, and sediment characteristics of the Sugar, Romaine, and Rock Creek basins, *with a section on* Surficial material, by J.W. Whitfield: Rolla, Missouri

Division of Geology and Land Survey Open-File Report 85-30-EG, 49 p.

Kleeschulte, M.J., and Emmett, L.F., 1986, Compilation and preliminary interpretation of hydrologic data for the Weldon Spring radioactive waste-disposal sites, St. Charles County, Missouri—A progress report: U.S. Geological Survey Water-Resources Investigations Report 85-4272, 71 p.

Kleeschulte, M.J., Emmett, L.F., and Barks, J.H., 1986, Hydrologic data for the Weldon Spring radioactive waste-disposal sites, St. Charles County, Missouri—1984-1986: U.S. Geological Survey Open-File Report 86-488, 61 p.

Kleeschulte, M.J., Mesko, T.O., and Vandike, J.E., 1985, Appraisal of ground-water resources of Barton, Vernon, and Bates Counties, Missouri: Rolla, Missouri Division of Geology and Land Survey Water Resources Report 36, 80 p.

Luckey, R.R., 1985, Water resources of the southeast lowlands, Missouri: U.S. Geological Survey Water-Resources Investigations Report 84-4277, 78 p.

Mesko, T.O., 1987, Subsurface geology of Paleozoic, Mesozoic, and Cenozoic units of southeast Missouri: U.S. Geological Survey Miscellaneous Investigations Map I-1875. [in press]

Missouri Department of Natural Resources, 1962-85, Census of Missouri public water supplies: Missouri Department of Natural Resources, Division of Environmental Quality, Public Drinking Water Program. [published intermittently]

_____ 1982, Energy resources and facilities map of Missouri: Jefferson City, Scale 1:500,000, 1 map.

_____ 1986a, Proposed ground water protection strategy, 1986: Jefferson City, 126 p.

_____ 1986b, Missouri water quality report, 1986: Missouri Department of Natural Resources, 70 p.

_____ 1986c, Facilities for solid waste disposal and processing: Missouri Department of Natural Resources, 6 p.

_____ 1986d, Confirmed abandoned or uncontrolled hazardous waste disposal sites in Missouri: Missouri Department of Natural Resources, Division of Environmental Quality Annual Report, 138 p.

Raisz, Erwin, 1954, Physiographic diagram, p. 59, *in* U.S. Geological Survey, 1970, National atlas of the United States: Washington, D.C., U.S. Geological Survey, 417 p.

Tauchen, R., ed., 1985, Missouri farm facts: Columbia, Missouri Crop and Livestock Reporting Service, 60 p.

U.S. Army Corps of Engineers, 1980, St. John's Bayou and New Madrid County floodway, Missouri: Memphis, Tenn., U.S. Army Corps of Engineers General Design Memorandum, Volume II, Phase I, Appendix II, p. A-54 to A-78.

U.S. Environmental Protection Agency, 1984, Classification of injection wells (section 146.5 of subpart A of part 146, underground injection control program; criteria and standards): U.S. Code of Federal Regulations, Title 40, Part 146, July 1, 1984, p. 371-372.

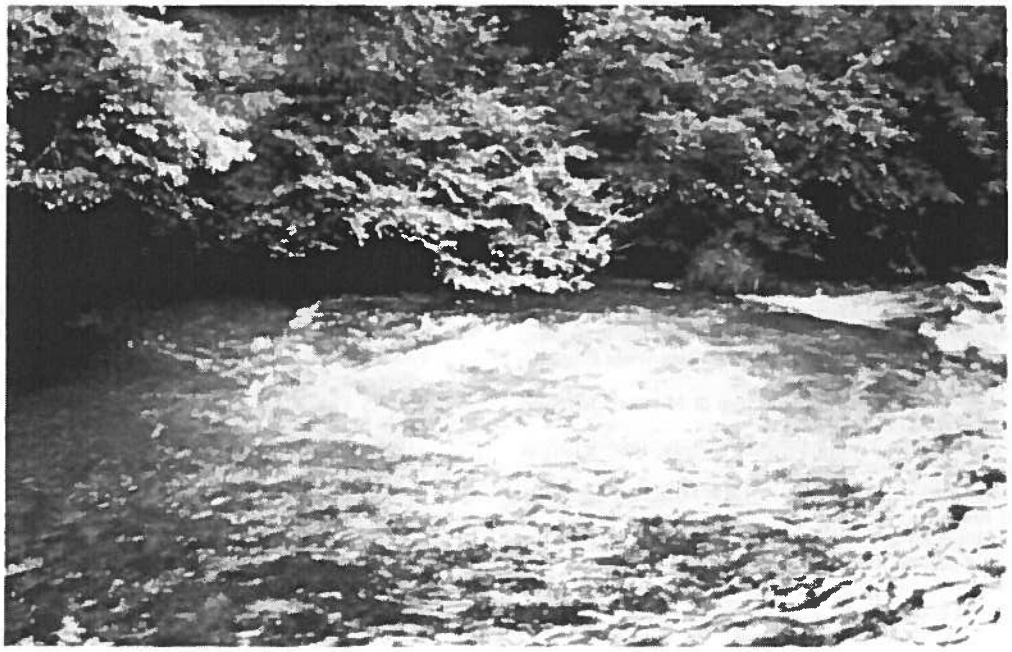
_____ 1986a, Maximum contaminant levels (subpart B of part 141, national interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 524-528.

_____ 1986b, Secondary maximum contaminant levels (section 143.3 of part 143, national secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 587-590.

_____ 1986c, Amendment to National Oil and Hazardous Substances Contingency Plan; national priorities list, final rule and proposed rule: Federal Register, v. 51, no. 111, June 10, 1986, p. 21053-21112.

_____ 1986d, National priorities list fact book—June 1986: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, report 4W-7.3, 94 p.

U.S. Geological Survey, 1985, National Water Summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p.



Greer Spring in southern Missouri. Greer Spring is the second largest spring in Missouri. (Photograph by James E. Vandike, Missouri Department of Natural Resources.)

Prepared by Thomas O. Mesko and Wayne R. Berkas

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, 1400 Independence Road, Mail Stop 200, Rolla, MO 65401